Senior Thesis

A Geochemical Interpretation of Water Quality in the Watershed of Big Walnut Creek, Central Ohio.

by
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Approved by:

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ABSTRACT

The elemental composition of the water in Big Walnut Creek is influenced by several physical processes that take place along the course of the stream, including mixing and dilution. Big Walnut Creek flows through the town of Gahanna, and subsequently mixes with channel and underground flow from Alum Creek and Blacklick Creek before discharging into the Scioto River. The chemical composition of water can be studied as two-component and three-component mixtures using graphical procedures. In addition, contaminants enter the channel in the form of sewage effluent which typically raise the concentration of sodium in the affected water. As Big Walnut Creek flows through the town of Gahanna the sodium increases 40 percent, which may be due to sewage effluent being discharged by the town. The mixing below the confluence of Alum Creek, Big Walnut Creek, and Blacklick Creek show major increases in sodium and strontium concentrations which are transported down from Blacklick and Alum Creek respectively. Big Walnut Creek enters the Scioto River and introduces a high calcium concentration, which mixes with high sodium and strontium concentrations of the Scioto River.

INTRODUCTION

Mixing is the process by which two or more components come together to form a mixture. Big Walnut Creek is an excellent waterway to study the effects of mixing because the chemical composition of the water can be represented as two- and three-component mixtures. By studying the changes in the chemical composition in Big Walnut Creek we can determine the influence of the different components entering the river in the form of tributaries, groundwater, and sewage effluent.

The watershed of the Big Walnut Creek in Figure 1 lies north-east of Columbus within the Scioto River Basin. The water in Big Walnut Creek originates from Hoover Reservoir east of Westerville, Ohio, and flows through the town of Gahanna (area A, Figure 1). Therefore, this stretch of Big Walnut Creek provides an opportunity to study the change in the concentrations of elements in water caused by input of sewage effluent and industrial waste water.

Further downstream, Big Walnut Creek mixes with water from Alum Creek and Blacklick Creek in Area B of Figure 1. Alum Creek enters Big Walnut Creek from the west, whereas Blacklick Creek enters from the east. The chemical composition of water in Big Walnut Creek is expected to change as a result of mixing of water contributed by these tributaries.

Finally, the water of Big Walnut Creek is discharged into the Scioto River (area C, Figure 1) causing the chemical composition of water in the Scioto River to change.

PROCEDURE

Twelve water samples were collected on December 5, 1992 from different localities along Big Walnut Creek and from nearby tributaries to study the effects of mixing on the chemical composition. All samples were collected in 500 mL polyethylene bottles which were rinsed with the water being collected. The bottles were immediately sealed and stored at room temperature. The sampling sites are marked in Figure 1.

Prior to analysis, the samples were filtered with 0.45 micron Millipore filters, acidified with 8 drops of concentrated HNO_3 to a pH of 2, and then transferred to new 250 mL polyethylene bottles. A small portion of each sample was used in rinsing the filtering equipment and the new 250 mL bottles. The samples were analyzed for K, Na, Ca, Mg, and Zn by Inductively Coupled Plasma Spectrometry (ICP). Potassium was not included in table 1 due to analytical difficulties.

To prepare the samples for analysis, 5 mL of copper sulfate were added to 45 mL of each water sample to act as an internal standard. Four mixed standards containing copper sulfate and all the elements being analyzed were run prior to the sample in order to establish the calibration curve. The element concentrations were then determined from this curve. Demineralized water was initially run through the ICP to set the zero points of the element concentrations.

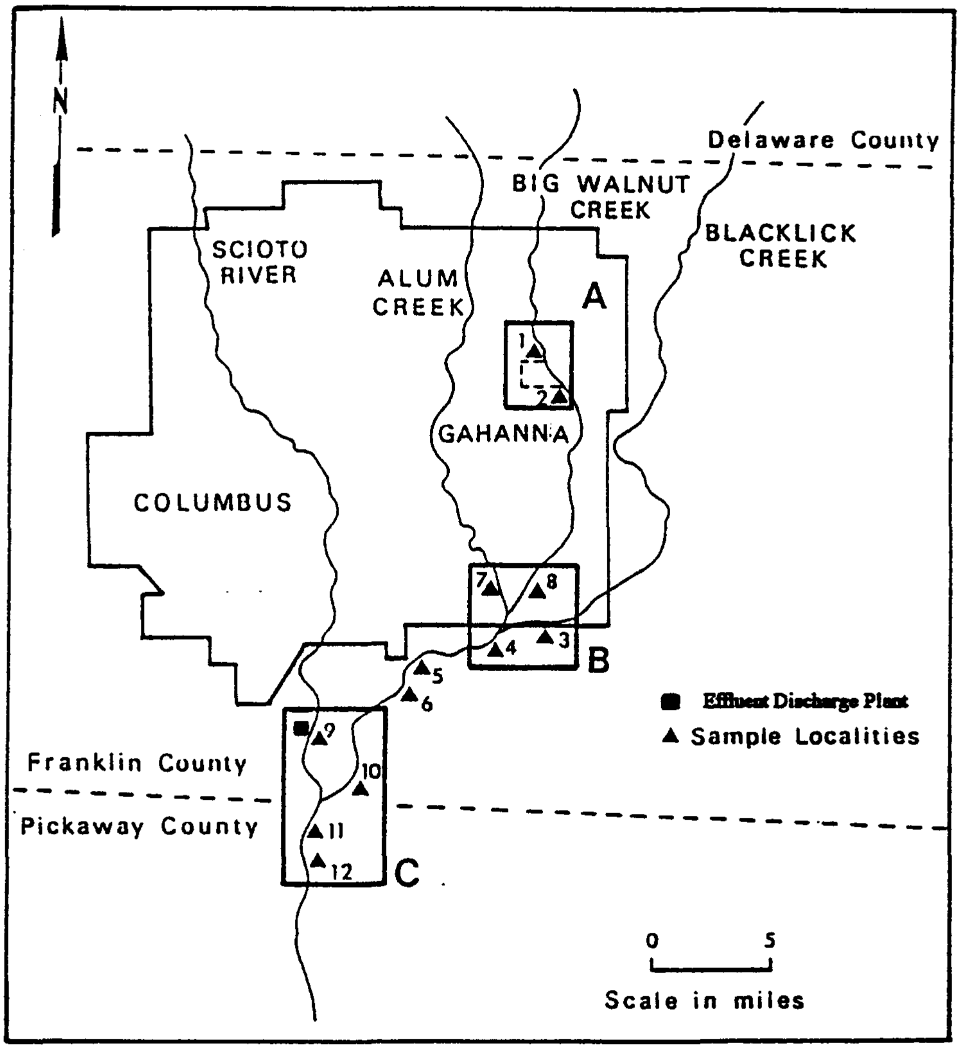

Figure 1. Map of Big Walnut Creek and surrounding rivers showing collection sites of water samples.

Each element was analyzed three times to improve the precision of the results. The average concentrations, their standard deviation, and standard errors are listed in Table 1. The standard deviation is defined as:

$$\sigma = \sqrt{\frac{(X - \bar{X})^2}{N - 1}} \qquad (1)$$

The corresponding error is:

$$E = (\sigma / M) * 100\ \% \qquad (2)$$

The magnitude of the errors in Figure 2 varies inversely with the magnitude of the concentrations of the respective elements. This relationship reflects the limitations of this (or any other analytical method) to precisely determine the concentrations of elements close to the limit of detection.

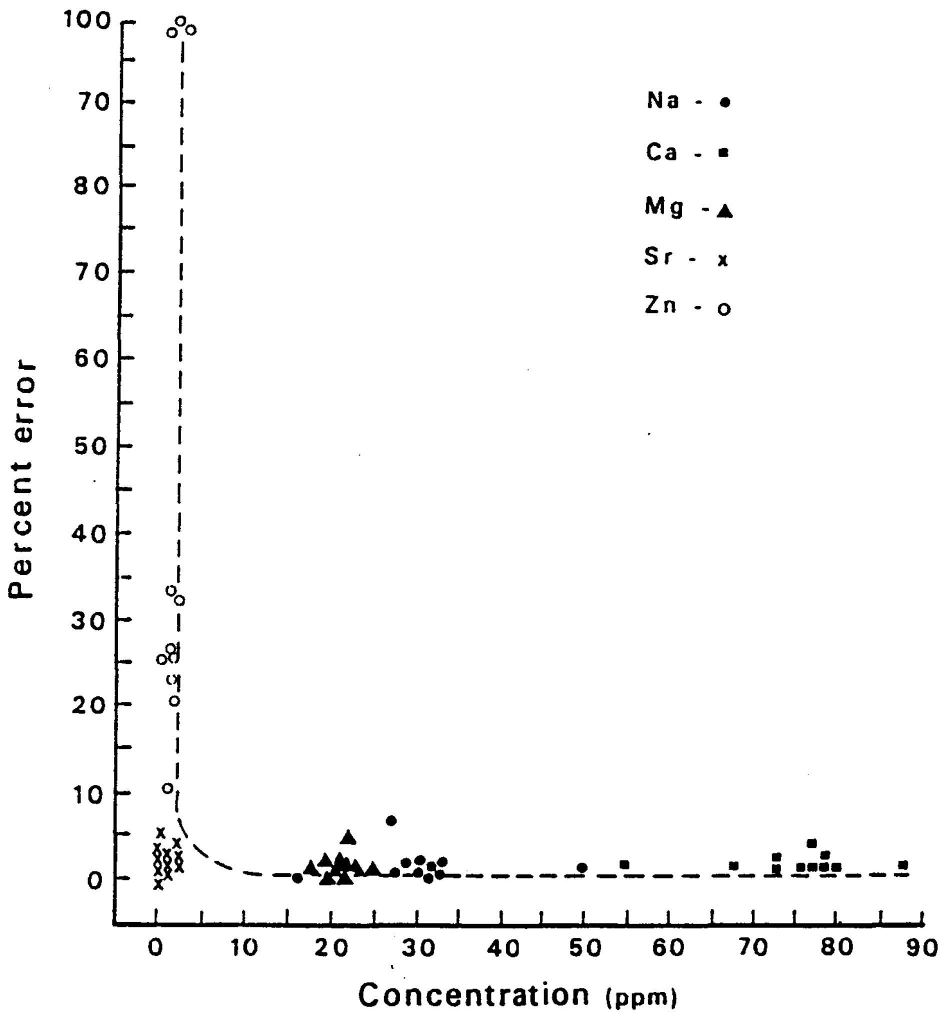

Figure 2. Concentrations of elements in parts per million verses the percent error.

Table 1. Concentrations of elements in units of parts per million of numbered water samples.

		Ca	Na	Mg	Zn	Sr
Sample 1		54.20	16.14	17.36	0.03	0.39
		54.11	15.92	16.98	0.03	0.37
		54.22	16.03	17.45	0.04	0.39
	Avg.	54.18	16.03	17.26	0.03	0.39
	SD	0.06	0.07	0.19	0.003	0.006
	%error	0.11	0.45	1.10	10	1.71
Sample 2		66.18	27.01	20.94	0.04	0.41
		66.42	26.64	20.59	0.04	0.40
		66.68	27.31	21.21	0.03	0.41
	Avg.	66.42	26.98	20.91	0.03	0.40
	SD	0.16	0.23	0.31	0.006	0.006
	%error	0.25	0.85	1.51	20	1.50
Sample 3		87.11	48.81	24.93	0.04	0.47
		86.91	49.66	25.54	0.03	0.50
		87.45	49.97	25.71	0.03	0.49
	Avg.	87.15	49.48	25.39	0.03	0.48
	SD	0.19	0.44	0.31	0.03	0.01
	%error	0.22	0.90	1.20	100	0.02
Sample 4		77.55	33.30	22.76	0.03	0.56
		77.42	32.67	22.39	0.04	0.55
		76.87	33.29	22.87	0.03	0.58
	Avg.	77.28	33.09	22.67	0.03	0.56
	SD	0.27	0.27	0.19	0.03	0.01
	%error	0.35	0.83	0.83	100	1.78
Sample 5		78.86	32.34	22.64	0.03	0.56
		78.67	32.60	22.70	0.03	0.56
		78.03	33.30	23.28	0.02	0.59
	Avg.	78.52	32.75	22.87	0.03	0.57
	SD	0.32	0.37	0.27	0.03	0.006
	%error	0.41	1.12	1.19	100	1.16
Sample 6		76.22	29.65	21.24	0.06	0.57
		77.99	30.55	21.90	0.04	0.55
		78.17	31.24	22.50	0.03	0.57
	Avg.	77.46	30.48	21.88	0.04	0.56
	SD	0.83	0.55	0.42	0.01	0.01
	%error	1.07	1.81	1.95	25	1.78

Table 1. continued

		Ca	Na	Mg	Zn	Sr
Sample 7		72.62	25.79	20.46	0.03	0.70
		72.43	25.70	20.22	0.03	0.67
		78.07	30.92	22.62	0.05	0.61
	Avg.	74.37	27.47	21.11	0.03	0.66
	SD	2.43	2.14	1.08	0.006	0.03
	%error	3.26	7.81	5.15	22	5.05
Sample 8		74.61	30.23	22.45	0.06	0.43
		74.97	30.55	22.42	0.04	0.41
		74.63	30.30	22.08	0.03	0.40
	Avg.	74.73	30.36	22.31	0.04	0.41
	SD	0.15	0.13	0.15	0.01	0.01
	%error	0.20	0.44	0.70	25	3.25
Sample 9		74.18	27.36	22.59		2.34
		70.04	27.41	21.81		2.15
		69.55	24.24	19.22		2.11
	Avg.	70.30	26.31	21.22		2.21
	SD	0.63	1.41	1.19		0.09
	%error	0.91	5.42	5.61		4.23
Sample10		75.00	28.12	21.45	0.04	0.52
		75.96	28.46	21.79	0.04	0.54
		75.87	27.47	20.98	0.07	0.55
	Avg.	75.61	28.01	21.40	0.05	0.54
	SD	0.41	0.36	0.28	0.01	0.01
	%error	0.53	1.31	1.33	26	1.85
Sample11		72.19	29.95	19.28	0.05	1.00
		72.65	30.68	19.95	0.02	0.96
		72.76	30.67	19.88	0.03	0.97
	Avg.	72.53	30.43	19.71	0.03	0.98
	SD	0.23	0.32	0.31	0.01	0.02
	%error	0.32	1.05	1.60	33	2.04
Sample12		73.30	31.31	20.28	0.04	1.01
		73.15	31.00	19.72	0.04	0.95
		73.41	31.53	20.37	0.02	0.98
	Avg.	73.29	31.28	20.12	0.03	0.98
	SD	0.09	0.22	0.27	0.01	0.02
	%error	0.12	0.71	1.34	33	2.04

PRESENTATION OF THE DATA

Calcium

The calcium concentration of the water samples in Big Walnut Creek varies from 79 ppm (Sample 5) to 54 ppm (Sample 1). In Area B (Figure 1), the concentration of calcium increases to 77 ppm below the confluence because the calcium content of the water in Blacklick Creek is 87.15 ppm. The Scioto River and the Big Walnut Creek mix in area C (Samples 11 and 12) and yield a combined calcium concentration of 73 ppm. The average calcium concentration of all water samples from Big Walnut Creek is 74.0 +/- 0.5 ppm (0.6%).

Sodium

The concentration of sodium in Big Walnut Creek increases from 16.0 ppm (sample 1) north of Gahanna to 33.0 ppm (sample 4) in area B of Figure 1. Blacklick Creek in area B has a sodium concentration of 49.5 ppm whereas Alum Creek shows a concentration of 27.5 ppm (sample 7).. The average sodium concentration throughout the river system is 28.2 +/- 0.45 ppm (1.4%). Mixing at the confluence in area B results in a sodium concentration of 33 ppm (Sample 4), and then decreases downstream. Big Walnut Creek has a sodium concentration of 28 ppm in area C (sample 10), similar to that of the Scioto river south of the confluence where a concentration of 30.4 ppm (sample 11) was recorded.

Magnesium

The magnesium concentrations of the water samples fluctuate very little throughout the course of Big Walnut Creek. The concentration of magnesium in Big Walnut Creek increases from 17.3 ppm (sample 1) in area A of Figure 1 to 25.4 ppm (sample 3) of area B. The concentration of magnesium below the confluence in area B (Sample 4) is 22.7 ppm. The magnesium content of Big Walnut Creek above the confluence in area C is 21.4 ppm (sample 10), whereas, the Scioto River has a magnesium concentration of 19.7 ppm (sample 11) just below the confluence. The average magnesium concentration of all water samples along Big Walnut Creek is 21.1 +/-1.8 ppm (8.4%).

Strontium

The concentration of strontium in Big Walnut Creek increases from 0.39 ppm (sample 1) north of Gahanna to 0.57 ppm (sample 5) south of area B Figure 1. The average concentration of strontium throughout the course of Big Walnut Creek is 0.49 +/-0.03 ppm (3.0%). Mixing at the confluence in area B generates a strontium concentration of 0.56 ppm in sample 4. Area C (sample 10) shows a concentration of 0.54 ppm above the confluence. As the waters from Big Walnut Creek mix with that of the Scioto River the strontium concentrations increase to 0.98 ppm (sample 11) because of the high Sr content of water in the Scioto River.

Zinc

The error in the zinc concentrations throughout Big Walnut Creek and its tributaries is +/- 45% on the average because the concentrations are close to the limit of detection. The average concentration of zinc is 0.03 ppm +/-0.03. Because of the high error, zinc will not be discussed from this point on.

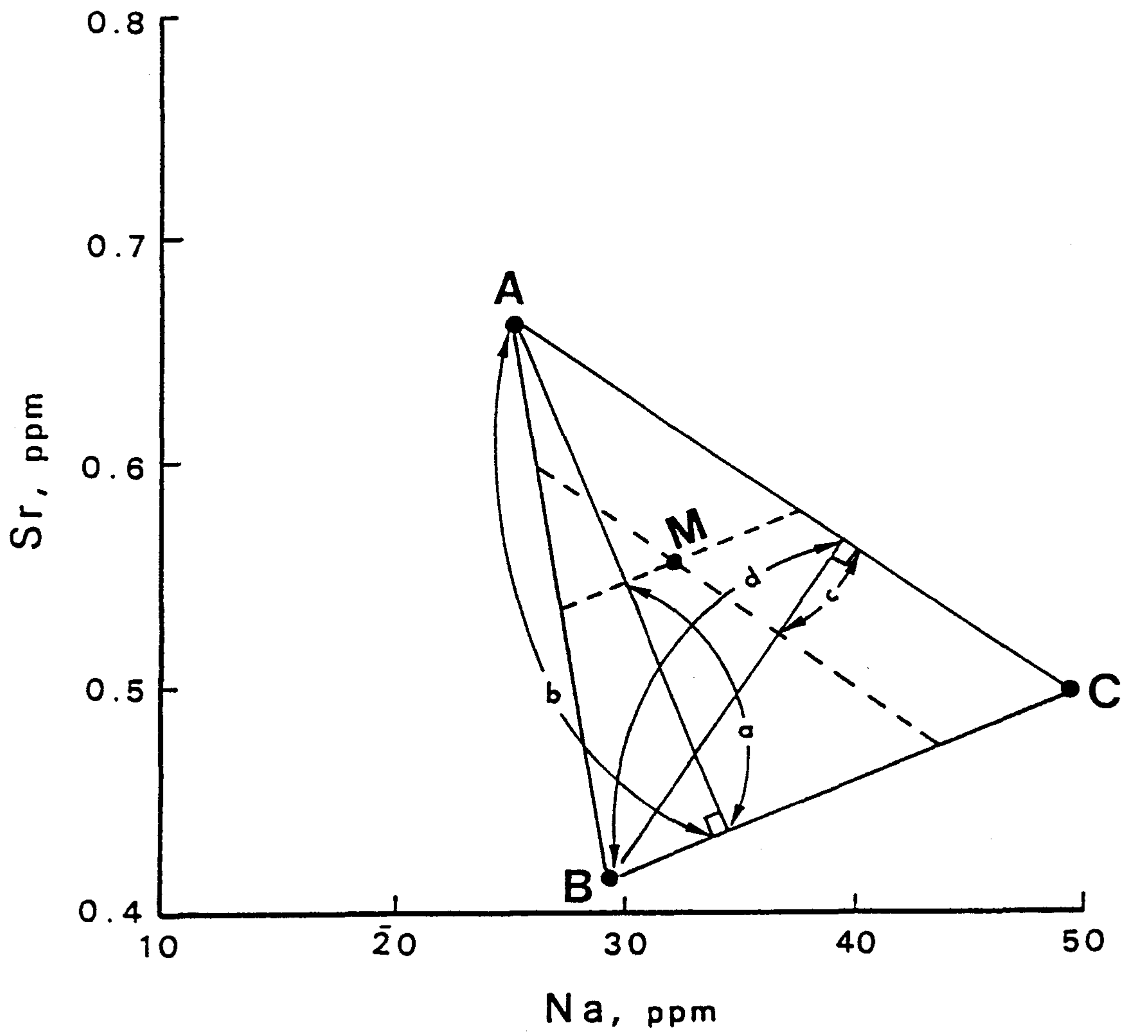

Figure 3. This diagram shows a 3 component mixture that is broken down to yield a fourth component. To determine Sr and Na concentrations of the fourth component the following analytical method is applied:

The quantity of A in M = a / b

The quantity of B in M = c / d

A + B + C = 100

C = 100 - A - B

VARIATION IN THE CHEMICAL COMPOSITION OF WATER IN BIG WALNUT CREEK

I have organized sections of Big Walnut Creek into areas A, B, and C for clarity, and will discuss each area respectively.

Area A

There are significant increases in elemental concentrations as Big Walnut Creek flows through Gahanna (Figure 1). Calcium concentrations increased 18 percent (Figure 6), and magnesium concentrations rose 17 percent. Strontium had a minimal increase in concentration of 0.02 ppm. Sodium concentrations rose from 16 ppm to 27 ppm, which is a 40% increase over the pristine conditions of the creek. The increases in the Na concentrations may be caused by the entry of groundwater into the stream and/or by the discharge of sewage effluent, and/or industrial waste water.

Area B

Area B in Figure 1 shows Blacklick Creek and Alum Creek entering the Big Walnut Creek. As these rivers converge, mixing takes place below the confluence. The concentrations of the three components are displayed graphically in Figure 4 in coordinates of the concentrations of Ca and Sr (Figure 4a) and Sr and Na (Figure 4b). In both diagrams the concentrations of these elements in sample 4 taken below the confluence plot inside the mixing triangle as expected. The Ca to Sr and Sr to Na ratios are listed in percentages in Table 3.

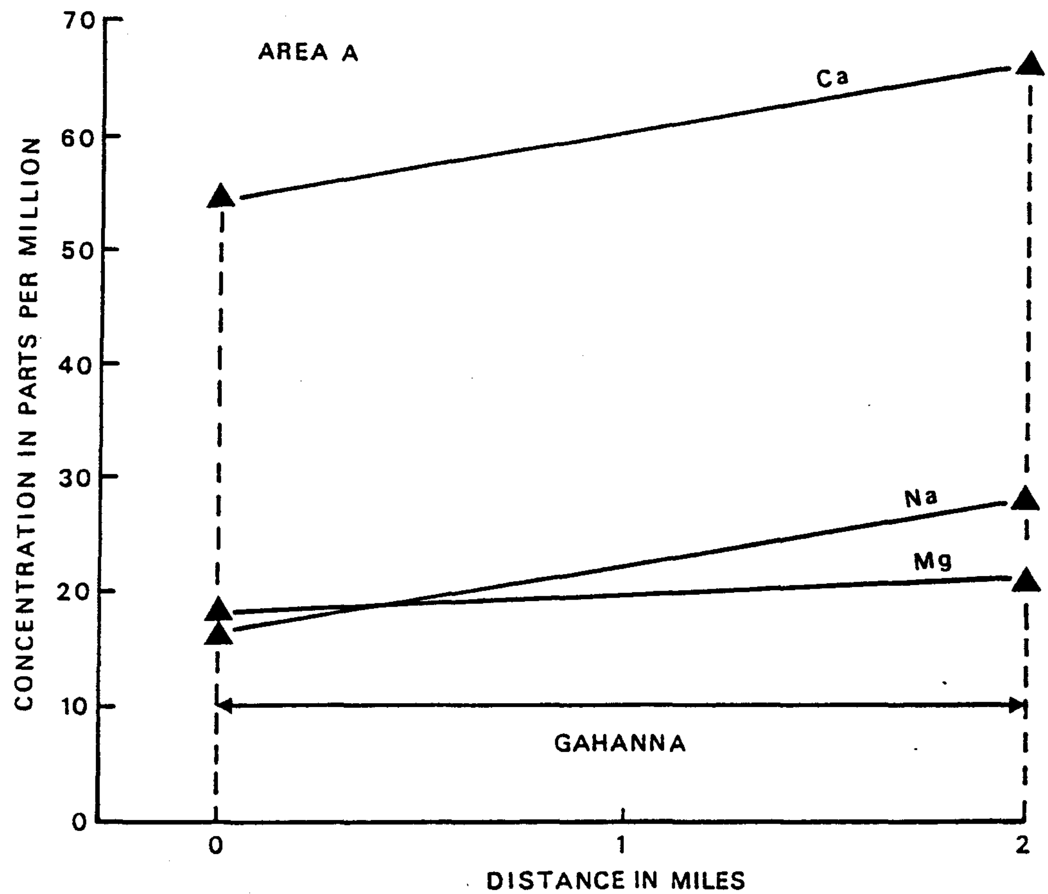

Figure 6. Concentration in parts per million of Ca, Na, and Mg as they fluctuate through the town of Gahanna. Sr was omitted because it would require a separate scale.

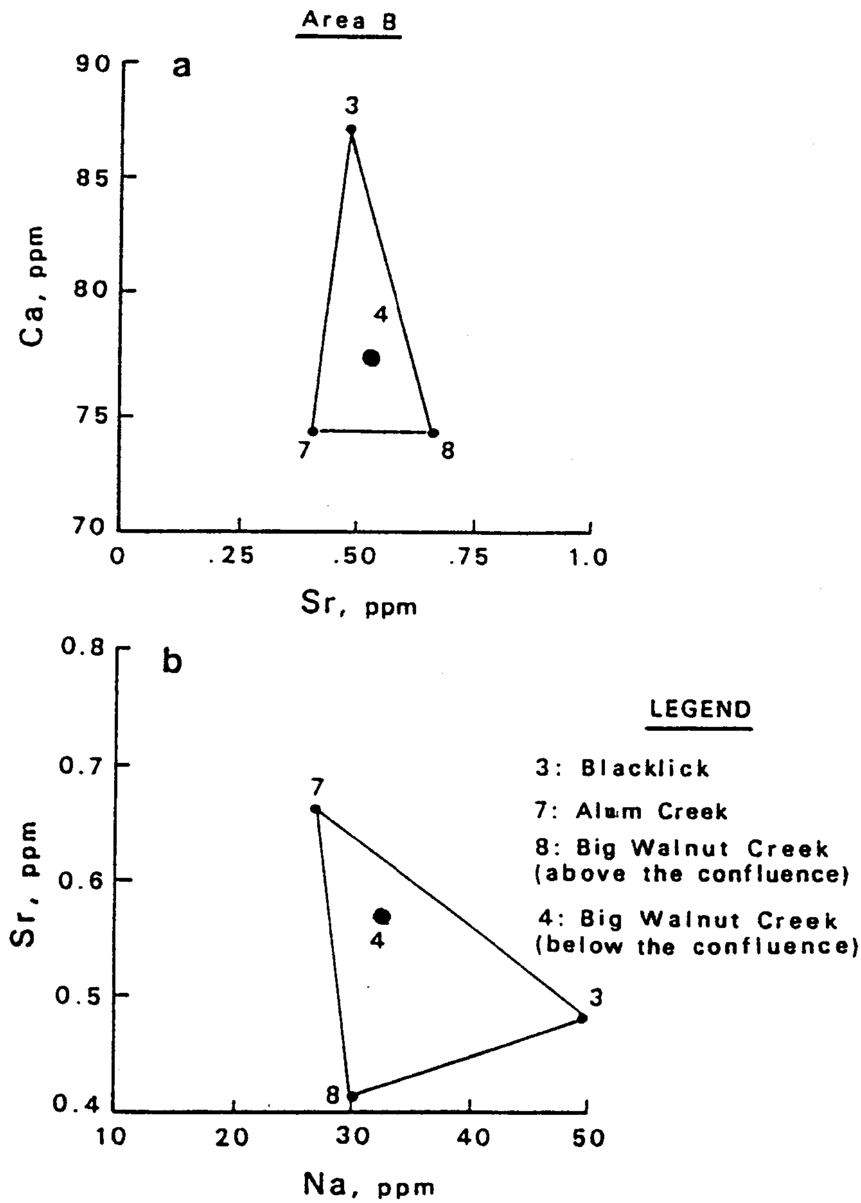

Figure 4. Strontium plotted verses calcium and sodium plotted verses strontium in the confluence of area B.

Table 3. Percentage breakdown, by sample number, of the three-component mixtures from area B (Refer to Figure 4). Determined by methods described in Figure 3.

ELEMENTS	Sample #	3	7	8
Ca - Sr		22%	33%	45%
Sr - Na		33%	42%	25%

Area C

Big Walnut Creek enters the Scioto River in area C (Figure 1). Big Walnut Creek brings a high concentration of Na into the Scioto River to yield a total concentration of 70.3 ppm. Sample 11 is a mixture of water from the Scioto River and Big Walnut Creek and therefore should lie on the mixing line connecting sample 9 (Scioto River) and sample 10 (Big Walnut Creek). Reference to Figure 5 indicates that samples 11 and 12 (Scioto River, below the confluence) are not located on the mixing line as expected. Evidently, a third component is pulling samples 11 and 12 away from the array. If this third component was not present, the concentrations of sodium in sample 11 would have been 27.8 ppm and the concentration of strontium would have been 0.9 ppm. The third component increases the Sr concentration slightly and decrease the Na concentration as it mixes with the Scioto waters (Figure 5). The third component is, most likely, an influx of groundwater into the stream.

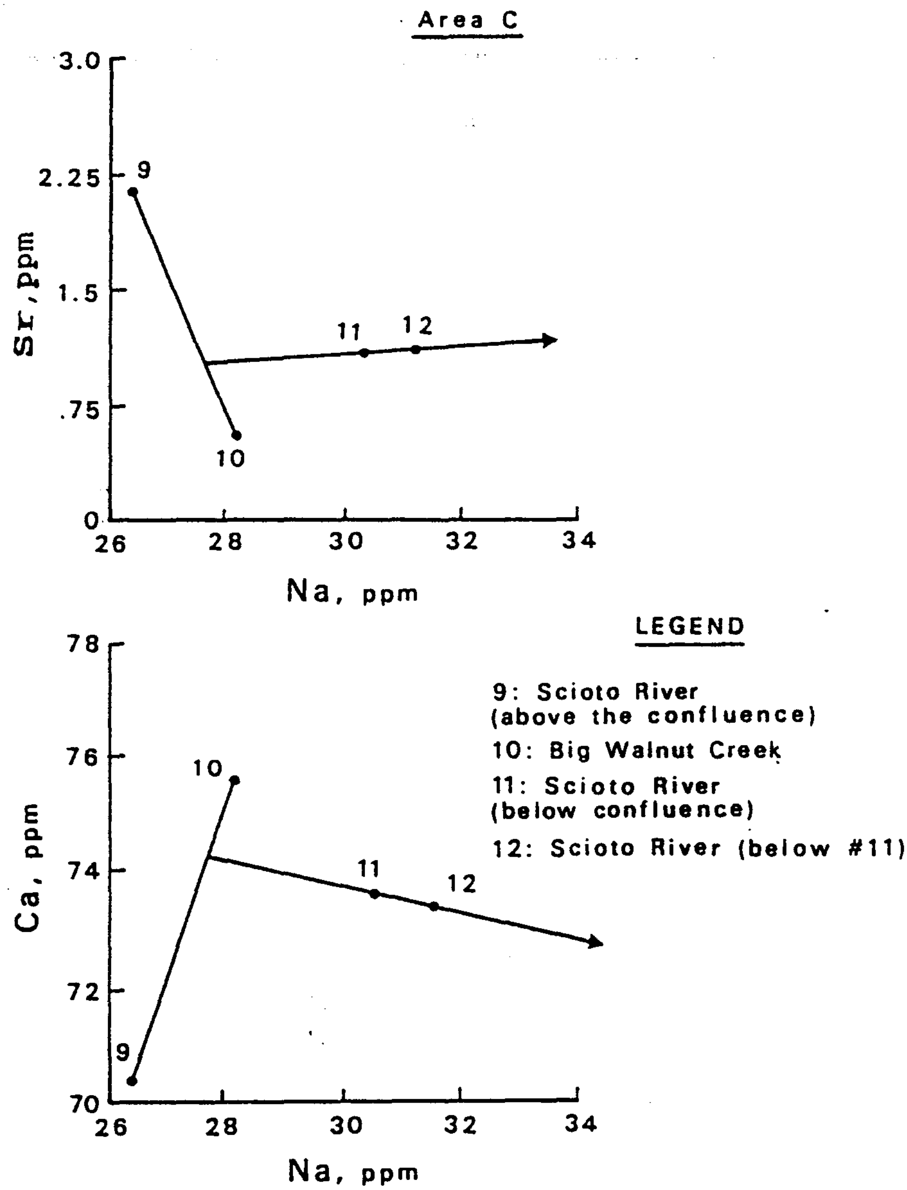

Figure 5. Sodium plotted against strontium and calcium in the confluence of area C.

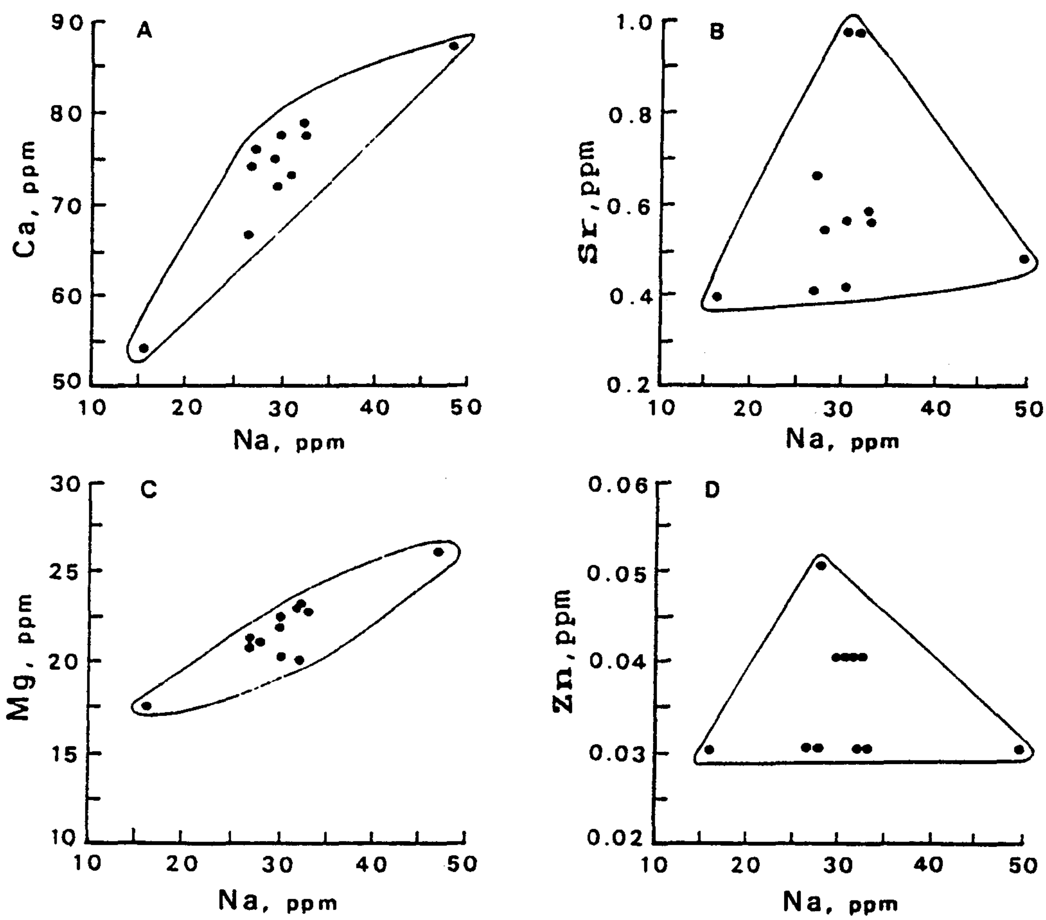

Figure 7. Concentrations of Ca, Mg, Zn, and Sr in parts per million (ppm), plotted against Na in ppm.

Sewage effluent is discharged in area C, northwest of sample 9 (Figure 1). The effluent has a high concentration of Na due to the salt intake by humans and the inability of humans to efficiently use large quantities of this element. Therefore, high quantities of Na are collected and discharged by the Columbus sewage treatment plants into the Scioto River. According to Figure 5, the amount of sodium in sample 11 is less than that of sample 12. I attribute this to incomplete mixing of the effluent plume as it migrates downstream.

SUMMARY OF CONCLUSIONS

The chemical composition of the water in Big Walnut Creek reflects the many processes taking place along its course. By studying the water within Big Walnut Creek as a series of mixtures, we can attempt to determine the source and composition of the water involved.

Big Walnut Creek shows increases in sodium as it flows through the town of Gahanna which could be due to sewage effluent discharged by the town.

The confluence (area B) below the intersection of Alum Creek, Blacklick Creek, and Big Walnut Creek demonstrates mixing. Strontium, calcium, and sodium were plotted to form mixing triangles in Figure 4. Sample 4 lies within these triangles and hence mixing takes place.

Area C shows the introduction of a third component that is pulling samples 11 and 12 away from the expected concentrations (Figure 5). This additional component could be the influx of groundwater into the system.

ACKNOWLEDGMENTS

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